AOP-95

SOLAR • THERMAL • ELECTRIC •

ANNUAL OPERATING PLAN
FISCAL YEAR 1995

October 1994

AOP95

Sandia National Laboratories
Albuquerque, New Mexico

NREL
National Renewable Energy Laboratory
Golden, Colorado

FOREWORD

This Annual Operating Plan (AOP) provides detailed plans for the fiscal year 1995 (FY95) activities of the Department of Energy's (DOE's) Solar Thermal Electric Program.

This year's plan is consistent with the Department of Energy's strategic intent and the Solar Thermal Electric Program's Five-Year Program Plan. It consists of a coordinated set of market-pull activities having private sector involvement in all phases ranging from initial planning through execution. Our partners include Fortune 500 manufacturers who foresee large domestic and worldwide markets for solar thermal electric components and systems, and major utilities for whom power tower and dish/engine systems play key roles in plans for environmentally benign, fuel-secure, distributed generation capacity by early next century. With over $150M of multiyear, 50/50 cost-shared cooperative projects in place during FY95, the federal budget's purchasing power is increased by more than 70 percent.

Significant cost-sharing is not the only indicator of the relevance and quality of the program's activities. In FY93, one of the program's joint venture products—a parabolic dish concentrator/free-piston Stirling engine system—won a prestigious R&D 100 Award from *R&D Magazine* as one of the 100 most significant research and development accomplishments of the year. This is an excellent example of government/industry cooperation with our private sector partner, Cummins Power Generation, continuing to improve the Stirling engine system as it moves closer to commercialization.

FY95 will see initial operation of the Solar Two power tower plant, development of Phase 3—Manufacturing Prototype Dish/Stirling Systems—by Cummins, and expansion of our operation and maintenance cost reduction partnership to additional SEGS plants. In addition, our new utility-scale dish/Stirling joint venture programs and our solar manufacturing initiative will begin to field hardware.

The DOE, its field laboratories (Sandia National Laboratories and the National Renewable Energy Laboratory), and its private and public sector partners are looking forward to a highly productive FY95.

Approved:

Craig E. Tyner
Manager
Solar Thermal Technology Development
Sandia National Laboratories

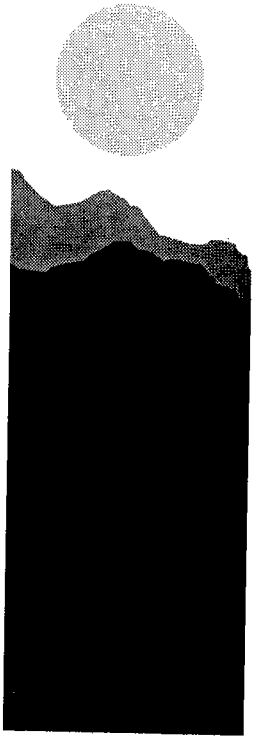
Approved:

Tom A. Williams
Program Manager
Solar Thermal Electric Program
National Renewable Energy Laboratory

Approved:

Gary D. Burch
Director
Solar Thermal and Biomass Power Division
U. S. Department of Energy

TABLE OF CONTENTS



OUR VISION

Our vision for solar thermal electric technology is the large-scale acceptance and installation of U.S.-designed and -manufactured solar thermal electric systems operating worldwide by the year 2000. We expect to realize this vision through a coordinated program of joint-venture projects, technology development and validation, and market conditioning.

OUR MISSION

The mission of the Solar Thermal Electric Program is to work with current and potential manufacturers and users of solar thermal electric technology to

- develop reliable and efficient solar thermal electric systems for generation of economically competitive power that can contribute significantly to the national energy mix and thereby reduce dependence on imported energy sources,
- increase acceptance of this technology as a candidate for cost-competitive modular power generation by utilities, industry, and manufacturer/user groups, both in the United States and abroad, and
- aggressively support the development of the industrial base required for this technology to penetrate the various energy applications and markets, creating new jobs and business opportunities for U.S. industry.

OUR STRATEGY

The Solar Thermal Electric Program strategy is consistent with the objectives set forth by the Office of Solar Energy Conversion in *Solar 2000 - A Collaborative Strategy.*[1] The Department of Energy (DOE) and its field laboratories (Sandia National Laboratories and the National Renewable Energy Laboratory [NREL]) will

- increase, through cooperative ventures, industrial participation in both the planning and execution of program elements. Specifically,

  The Solar Two molten-salt power tower project led by Southern California Edison (SCE) will provide the technical base for Solar 100, the first 100-MW power tower plant.

  The Cummins Power Generation, Inc. (Cummins) 7-kWe dish/Stirling system, designed for both remote and grid-connected applications, will be operated at utility and industrial sites.

  The Utility-Scale Joint-Venture Program (USJVP) for 25-kWe dish/Stirling systems will field initial hardware, with the last phase of this program resulting in at least one megawatt of dish/engine system capacity installed by utilities.

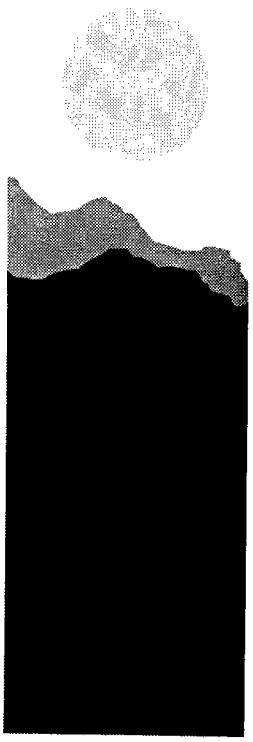
  The operations and maintenance cost reduction study with the Kramer Junction Company Operating Company (KJC) will provide for lower levelized energy costs for power tower and dish/engine solar systems as well as trough plants.

- utilize the analytical and experimental capabilities of the program to support and enlarge solar thermal technology base and the user, supplier, and decision-making constituency. Specifically,

  Industry/laboratory teams will extend the performance and reliability of critical system components (concentrators, receivers, optical materials, etc.) through focused research and development.

  Industry and user requests for assistance will be addressed by the Solar Thermal Design Assistance Center and other program resources.

  Information exchange through conferences, road shows, and publications will be used to bring the technology to the attention of regulators, potential users, and the public.



[1] *SOLAR 2000, A Collaborative Strategy*, Office of Solar Energy Conversion, United States Department of Energy, Washington, DC, February 1992.

OUR STRUCTURE

The Solar Thermal Electric Program is structured to provide a balance of activities to exploit near-term commercialization opportunities, meet long-range performance and cost goals, and maintain a forward-looking research thrust to open new opportunities.

Program activities include the following:

I. Commercial Applications

- A. Power Tower Cooperative Projects
- B. Dish/Engine Cooperative Projects
- C. System Operation and Maintenance Cost Reduction
- D. Design Assistance
- E. Solar Manufacturing Initiative
- F. Commercialization

II. Technology Development

- A. Concentrator Technology
  1. Heliostats
  2. Parabolic Dishes
  3. Optical Materials
- B. Power Conversion Technology
  1. Power Tower Technology
  2. Dish Receiver Technology
  3. Dish Converter Solarization Technology
- C. Testing Technology

III. Reimbursables

Management and reporting functions are detailed later in the Management and Implementation Plan.

ACTIVITY OVERVIEW

COMMERCIAL APPLICATIONS

At the initiative of our industrial partners, our objective is to collaborate with and/or cost share in the development of fully integrated systems that will result in (1) competitive solar thermal electric systems based on refinement and optimization of current technology, and (2) advanced solar thermal electric systems that will improve performance and cost competitiveness in the late-1990s and beyond.

Key activities include the following:

- initiate operation of prototype system under the Utility-Scale Joint-Venture Program. (FY95)
- initiate operation of the Dish/Stirling Joint-Venture Program manufacturing prototypes for remote applications. (FY95)
- initiate start-up of Solar Two, the utility-scale molten-salt power tower pilot plant. (FY95)
- finalize documentation of methods and system design features that are necessary to reduce operations and maintenance costs of utility-scale solar thermal power plants. (FY95)
- initiate cost-shared contracts to address manufacturing and cost reduction issues related to early-market heliostat production.

TECHNOLOGY DEVELOPMENT

The objective of our technology development program is to develop cost-effective concentrators, optical materials, and receiver and engine components to establish commercial readiness of solar thermal electric technology to penetrate major national and international markets by the late 1990s.

Key activities include the following:

- demonstration of advanced optical materials in large-scale field systems. (FY95)
- commercial development of pilot-scale next-generation optical materials. (FY96)
- field testing a natural-gas/solar hybrid reflux receiver as part of a dish/Stirling system. (FY95)
- demonstration of 500-hour operation of a reflux receiver suitable for 25-kW_e systems. (FY95)
- initiation of a CRADA with industry for development of an advanced molten-salt power tower receiver. (FY95)
- fabrication of initial prototypes of advanced heliostats and dish concentrators based on manufacturing concepts proven in other industries. (FY96)

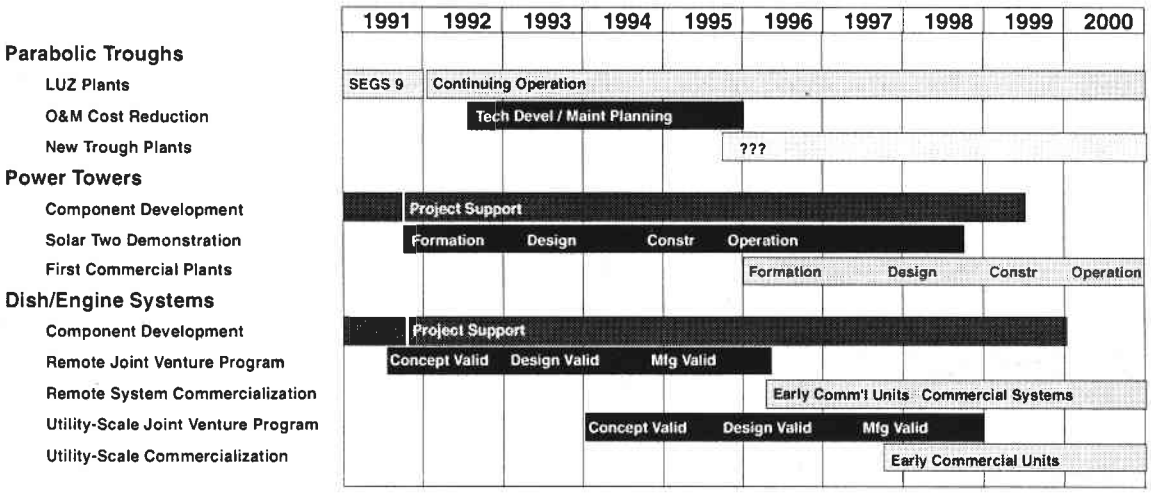
REIMBURSABLES

The objective of our reimbursables activity is to make the unique capabilities of the program's technologists and facilities available to other government agencies and industry, in order to maintain a more vigorous and flexible laboratory presence at no additional cost to the program.

The following is the key activity in this program:

- install a Cummins dish/Stirling system at a U.S. military installation. (FY95)

TIME TABLE



I. COMMERCIAL APPLICATIONS

Our program emphasizes two major categories of modular solar thermal technology: power towers (central receiver systems) and parabolic dish/engine systems. These two types of systems can satisfy utility needs for capacities ranging from a few kilowatts to hundreds of megawatts. We also support existing parabolic trough collector systems for the purpose of operation and maintenance (O&M) cost reduction. The 354 megawatts of installed capacity at the nine SEGS parabolic trough plants represents $1.2 billion of capital equipment and an invaluable source of information regarding solar thermal electric power plant operating experience. Much of this experience is appropriate for power tower and dish/engine system operations.

The program focuses on cost-shared activities with significant industrial involvement in the planning and execution of activities. These government/industry partnerships are comprised of teams uniquely qualified to rapidly advance the technology. The partnerships combine the manufacturing, marketing, and management skills of industry with the solar-specific experience base and analytical and experimental capabilities of the national laboratories.

During FY95, five major 50/50 cost-shared cooperative activities will be underway within the program with a total value of over $150M. The following organizations are the private sector leaders of these joint activities:

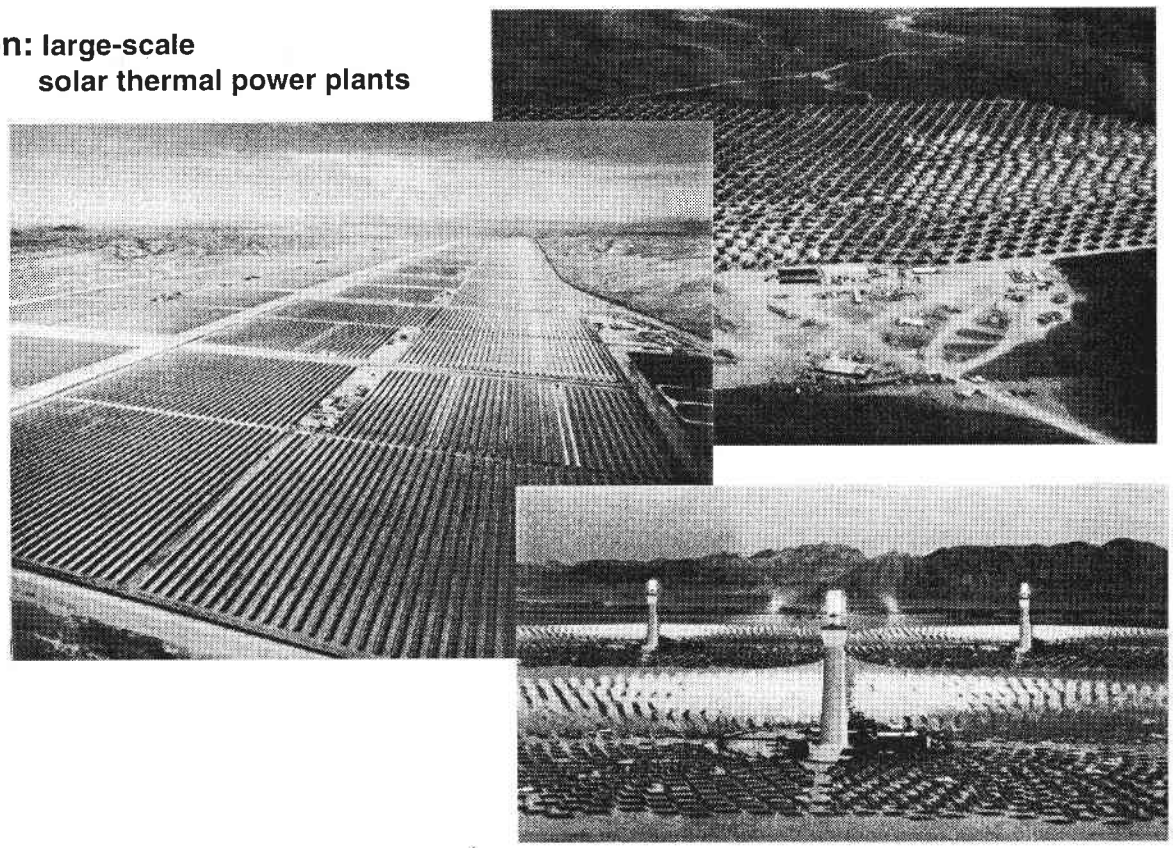
A. Southern California Edison and a consortium of other utilities and industry partners (power towers)

B. Cummins Power Generation and Science Applications International Corporation (SAIC) (dish/engine systems)

C. Kramer Junction Company Operating Company (system O&M cost reduction)

In order to better serve these and other partners interested in commercializing the solar thermal electric technologies, key personnel from headquarters and the laboratories will be trained in the latest aspects of technology transfer, market development, and commercialization. Increased awareness of the issues and techniques involved will allow us to conduct our market-pull activities more efficiently.

Our Vision: large-scale solar thermal power plants



A. POWER TOWER COOPERATIVE PROJECTS

Objective

To facilitate the commercialization of solar power tower technology for utility central power generation by the late 1990s, through the large-scale validation of the technology.

Rationale

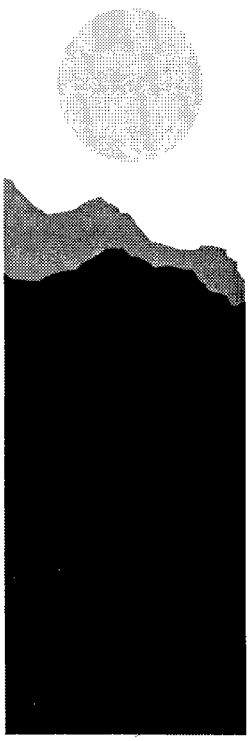
Utilities, public utility commissions, and investors are looking for clean, renewable energy sources to provide the power for the new generating capacity that will be needed in the Western States by the latter part of this decade. Molten-salt power tower power technology has the necessary capabilities to meet many of the needs and is on the brink of commercialization. The technical feasibility of power towers has been proven; cost, performance, and reliability can be predicted effectively. However, because of the large capital investment required for the first commercial plants and the risks perceived by utilities and investors, large-scale validation is needed as a precursor to commercialization of this technology. This large-scale validation is the Solar Two Project, a reengineering of the 10-MW Solar One power tower plant. The Project is being cost-shared by a consortium of utilities (Southern California Edison, Los Angeles Department of Water and Power, Idaho Power Company, PacifiCorp, Sacramento Municipal Utility District, Arizona Public Service Company, Salt River Project, and Nevada Power), agencies (California Energy Commission, Electric Power Research Institute, and South Coast Air Quality Management District), industry (Bechtel Corporation, Chilean Nitrate Corporation, and Rockwell), and the Department of Energy.

In order to support the commercialization of this technology, our efforts are focused in four key areas: (1) supporting the utility-consortium's effort to implement the Solar Two Project; (2) increasing the awareness of utilities, public utility commissions, and investors of power tower technology and its capabilities; (3) transferring DOE-developed technology, and supporting industry and the utilities in utilizing the technology to support commercialization efforts; and (4) supporting in the assessment and development of the first commercial power tower plants. In addition, the activities in Task II. B.1—Power Tower Technology Development—will continue to refine and improve the power tower technologies for the future.

FY94 Accomplishments

The five-year, $48-million Solar Two Project is continuing on schedule and on budget. Solar Two is a utility/industry-led, cost-shared project to reengineer the Solar One Pilot plant with a molten-salt heat-transfer system, including a molten-salt receiver and thermal energy storage system. This year, the old oil/rock thermal storage system from the Solar One Project was removed and the site certified clean so that construction of Solar Two could begin. Phase 2 of the Solar Two Project, Development of Major Bid Packages, was completed in March. Contracts for all of the major salt systems have been placed. Rocketdyne is building the receiver; ABB Lummis, the steam generator; and Pitt-Des Moines, the thermal storage tanks. Most of the other salt-related equipment has been ordered. Sandia, as chair of the Solar Two Technical Advisory Committee (TAC), organized and conduced five TAC meetings and numerous TAC subcommittee meetings to review the specifications, proposals, documents, and designs. We continue to work closely with SCE and Bechtel to ensure the success of the Project. The final engineering and initiation of construction, Phase 3, is nearing completion and construction will begin early in FY95. A commercialization plan was developed this year by the Solar Two Commercialization Advisory Board. This plan, in conjunction with Solar Enterprise Zone activities, offers a path for commercialization of power tower technology.

We continued to increase awareness of power tower technologies through presentations to utilities, industry, and state and federal agencies. In addition, Sandia conducted a number of independent studies and analyses to evaluate issues and design options related to Solar Two and commercial plants, working with SCE, Sacramento Municipal Utility District, and Arizona Public Service Company to investigate the use of power towers in their service areas. NREL initiated a study of hybridization options for power tower systems.



FY95 Task Description

In FY95, the Solar Two Project will complete Phase 3, Final Engineering and Initial Construction, and Phase 4, Construction. Solar Two will be ready for startup near the

end of the fiscal year. Sandia will continue to participate on the Solar Two Project team with SCE and Bechtel; we will participate in the Steering Committee as a non-voting member; we will chair the TAC; and we will contribute as members of the Commercialization Advisory Board. As chair of the TAC, Sandia will continue to organize the quarterly TAC reviews and the subcommittee reviews of specifications and proposals. In addition, Sandia will support the testing and evaluation of Solar Two through input into the test and evaluation plans and by providing personnel to support the testing and evaluation. This level of participation in the Solar Two Project will enable DOE-developed expertise to be utilized to increase the potential for the success of this project. We will look for other cost-shared activities to advance the commercialization of the power tower technology, including hybridization options. Cost-shared studies with interested utilities for evaluating the use of power tower on their systems will be continued. Opportunities for first commercial power tower power plants will continue to be explored.

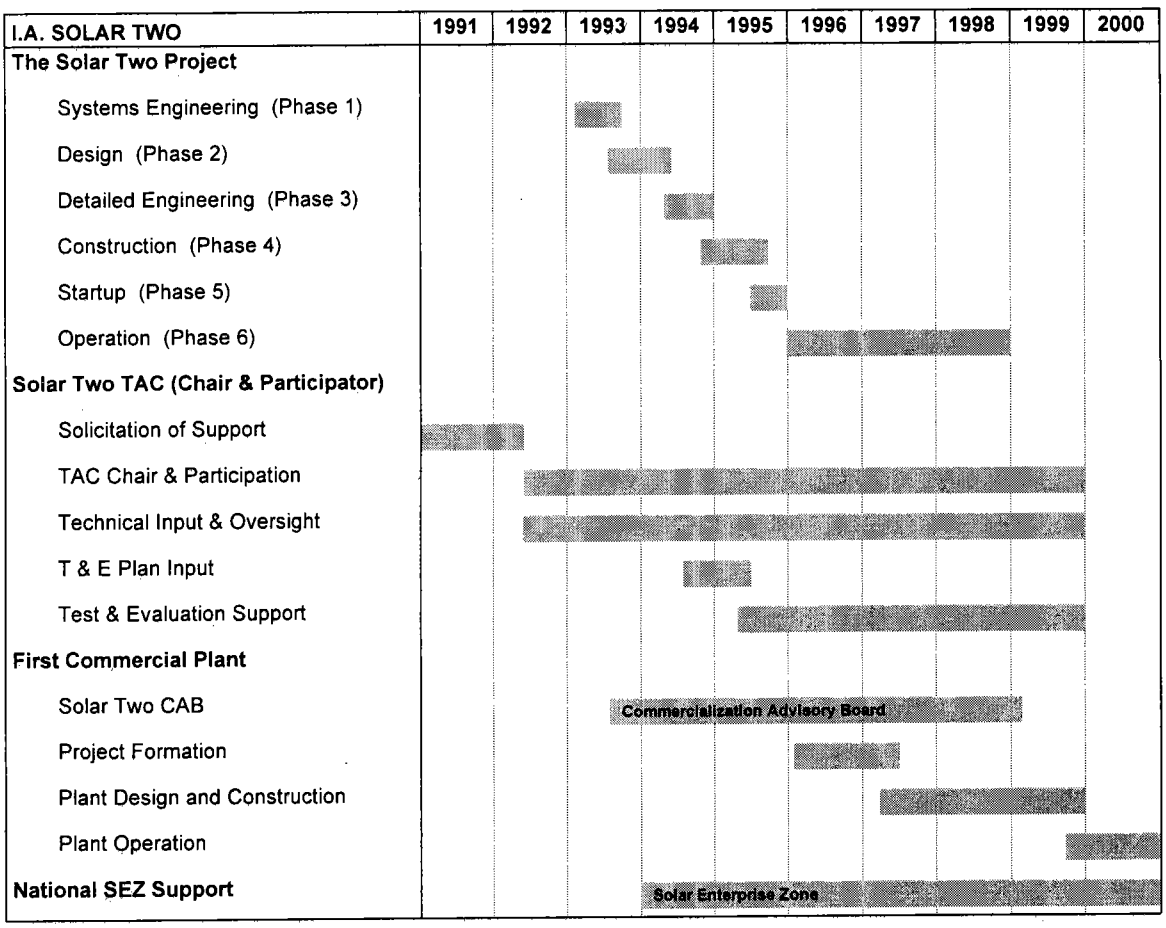
Major Milestones

Nov 94	Complete Phase 3, Final Engineering and Initial Construction.
Jul 95	Initiate Plant Startup process.
Sep 95	Complete Phase 4, Plant Construction and begin Phase 5, Startup.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	600	0	0	600
Contracts	0	0	1500	1500
Total	600	0	1500	2100

Time Table



B. DISH/ENGINE COOPERATIVE PROJECTS

Objective

To commercialize economically competitive dish/engine solar thermal electric systems for remote and utility markets.

Rationale

U.S. industry and electric utilities have determined that solar thermal electric generating systems based on a parabolic dish concentrator and a Stirling engine can be economically competitive in several markets by the late 1990s. The Dish/Stirling Joint-Venture and the Utility-Scale Joint-Venture programs (DSJVP and USJVP) offer industry the opportunity to realize this market/technology goal on a faster time scale and at a lower technical and financial risk than otherwise possible. The objective of the DSJVP with Cummins Power Generation, Inc. is to develop a 5- to 10-kW_e dish/Stirling system for remote power markets. The remote power markets offer the earliest potential for market penetration. Dish/engine systems are also expected to be competitive in the larger utility markets, both in the United States and internationally. The objective of the USJVP, which is another set of 50/50 cost-shared partnerships with industry, is to develop 25-kW dish/engine systems suitable for the electric utility market.

FY94 Accomplishments

In FY94, cost-shared contracts with Science Application International Corporation (SAIC) and Cummins were placed under the USJVP. Cummins also continued to work towards successful completion of Phase 2 of the DSJVP.

Phase 2 of the DSJVP was extended by 10 months, primarily as a result of delays caused by changing from the Sunpower to the Clever Fellows Innovation Consortium (CFIC) engine for the Cummins 7-kW_e dish/Stirling system. The CFIC free-piston Stirling engine/linear alternator was selected because of its balanced, vibration-free operation and manufacturability, and because it has the potential for longer life and higher efficiency than the Sunpower machine. In FY94, Cummins also made significant advances in concentrator mirror manufacturing, receiver durability, and controls/power conditioning development.

Several technically responsive proposals for the USJVP were received in October 1992. All of these proposals were for 25-kW_e dish-Stirling systems. Based on the costs of the best and final offers and available funding, negotiations were initiated with SAIC and Cummins, and contracts were placed in November 1993 and January 1994, respectively.

The SAIC USJVP team includes Stirling Thermal Motors (STM) and Detroit Diesel Corporation (DDC). SAIC is the systems integrator and also supplies the dish concentrator for the system; STM provides the Stirling engine and thermal receiver; and DDC provides the long-term manufacture of the cold parts of the engine and design for engine manufacturability. In the 10 months since the contract was placed, the SAIC team made considerable progress toward fielding a prototype dish/Stirling system, including the following: design of the next-generation faceted dish; the fabrication and/or procurement of all parts for the dish; fabrication, assembly, and testing of their first solar power conversion system (receiver and engine); and selection and preliminary preparation of their dish/Stirling system test site.

Design work on the Cummins USJVP system was also initiated. The concentrator will be a new technology for Cummins—a "true" parabola that employs gore-shaped, glass/metal facets. The engine is a scale-up of the 7-kW_e CFIC engine being developed in the DSJVP. The control system and power-conditioning system will also draw extensively on work that has been done in the DSJVP.

Sandia and NREL continued to provide valuable technical support—primarily in areas of solar thermal expertise—for the joint ventures in FY94. The key issues of heat-pipe and pool-boiler receiver design and optical materials, in particular, received technical support from the laboratories. We also provided optical evaluation and system analysis support to our industrial partners.

FY95 Task Description

With the establishment of a "design level" system in Phase 2 of the DSJVP, Phase 3 will emphasize manufacturing and system refinements; application-based development —such as water pump, remote village, and

hybrid receiver controls—will also be addressed. As part of Phase 3, at least 10 systems will be manufactured and installed at host test sites. One system is scheduled for delivery to the Texas Utilities site in Dallas, Texas, in December 1994, and one system is scheduled for delivery to the Central and Southwest/EPRI site in Ft. Davis, Texas, in March 1995. In early FY96, Cummins plans to deliver two systems to Nevada Power and one system to Arizona Public Service; a system is scheduled for the California Polytechnic University test site in Pomona, California; and two systems are scheduled for the AT&T test site in Phoenix, Arizona. Sandia is scheduled to receive a hybrid system in 1996. Several other systems (outside the DSJVP) will also be manufactured and delivered to Cummins customers in the next two years, including a system for the Department of Defense (DoD) (see Section III).

In FY95, the SAIC team is scheduled to complete Phase 1 and to start Phase 2 of their project. The activities that must be completed in Phase 1 include integration and operation of the dish/Stirling system, completion of extended laboratory testing of engines, and fabrication of a hybrid/direct-insolation receiver. Phase 2 involves fabrication of an alternate receiver design, down-selection of the receiver design, and redesign and fabrication of five complete dish/Stirling systems for installation and testing at utility-selected sites.

The work on the Cummins USJVP Phase 1 conceptual design will continue in FY95. The manufacturing and construction of prototype equipment will be initiated. The system components, e.g., the solar concentrator, will be tested on an individual basis. However, a fully integrated system test will not occur until FY96. Testing of a back-up Northern Research and Engineering Corporation (NREC) Brayton engine in a test cell will also be initiated.

Sandia and NREL will continue to provide technical support for the joint ventures. Laboratory technology transfer and support will emphasize key areas of solar expertise such as receiver design, optical materials, and systems analysis. The loan of specialized equipment such as the Sandia Beam Characterization System and NREL's Scanning Hartman Optical Test (SHOT) will be provided as resources permit.

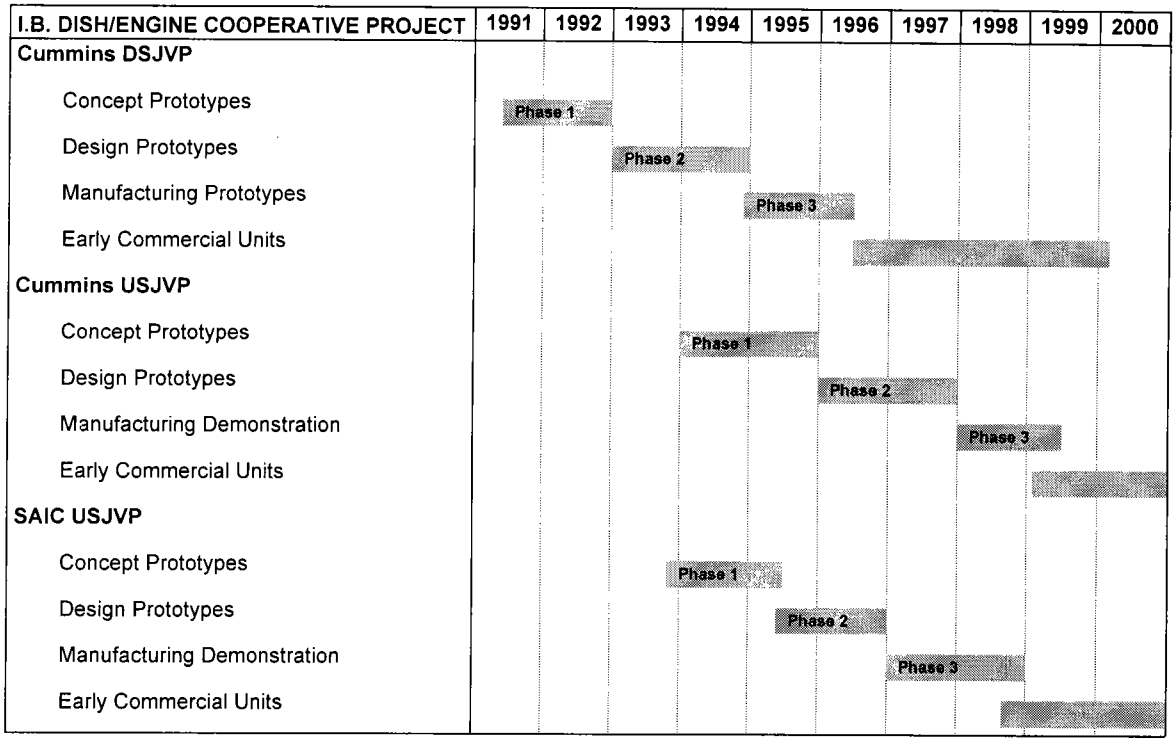
Major Milestones

Nov 94	Install/test an SAIC dish concentrator.
Dec 94	Complete Phase 2 of the DSJVP.
Mar 94	Deliver a Cummins 7-kW_e system to Texas Utilities' Dallas test site.
Apr 95	Begin integrated operation of the complete SAIC dish/Stirling system.
Apr 95	Deliver Cummins 7-kW_e system to Central and Southwest's Ft. Davis test site.
Mar 95	Fabricate and test Cummins USJVP prototype control systems.
Apr 95	Initiate back-up NREC Brayton engine test cell testing at Cummins.
Jun 95	Complete SAIC USJVP Phase 1; begin Phase 2.
Jul 95	Install and test two prototype USJVP concentrators at Cummins.
Sep 95	Fabricate first Cummins prototype 25-kW_e Stirling engine.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	550	30	0	580
Contracts	7583	65	368	8016
Total	8133	95	368	8596

Time Table


I.B. DISH/ENGINE COOPERATIVE PROJECT
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Cummins DSJVP
Concept Prototypes
Design Prototypes
Manufacturing Prototypes
Early Commercial Units
Cummins USJVP
Concept Prototypes
Design Prototypes
Manufacturing Demonstration
Early Commercial Units
SAIC USJVP
Concept Prototypes
Design Prototypes
Manufacturing Demonstration
Early Commercial Units
Phase 1
Phase 2
Phase 3
Phase 1
Phase 2
Phase 3
Phase 1
Phase 2
Phase 3

C. SYSTEM OPERATION AND MAINTENANCE COST REDUCTION

Objective

To work closely with industry to reduce the costs associated with operating and maintaining utility-scale solar thermal electric generating plants through research and development based on the extensive operating experience of Kramer Junction Company and other SEGS plants.

Rationale

The nine Solar Electric Generating System (SEGS) power plants located in Southern California are the only utility-scale solar power plants currently operating in the world, with an existing capacity of 354 MW. The costs associated with operating and maintaining solar thermal plants have a significant influence on the economic viability of the technology. For example, operation and maintenance costs account for approximately 25% of the SEGS electricity costs. Reductions in O&M costs would enhance the marketability of solar thermal technologies, such as the Solar Two Project and commercial power tower plants (see Section I.A.), currently being developed by the program. Power tower plants have many of the same subsystems contained within a SEGS plant, and the O&M of these subsystems would be similar. In addition, the five co-located SEGS plants at Kramer Junction, California, comprise the world's first solar power park. Commercialization plans by U.S. industry have recommended that future, large-scale deployment of grid-connected solar technologies be in power parks. This project is also addressing issues related to the management and optimization of these types of large facilities.

The goal of this activity is to reduce O&M costs associated with utility-scale solar thermal power plants. This is being accomplished by characterizing O&M costs incurred at the SEGS plants during more than 40 plant-years of operation. Research and development is then performed to reduce the cost of the most important categories. The assessment of the important categories at SEGS plants indicated that roughly two-thirds were applicable to O&M at power tower plants. This guarantees that this initiative will benefit not only current solar thermal technology (SEGS troughs), but future technologies as well.

The initiative is being performed on a 50/50 cost-shared basis between owners of the SEGS plants (primarily U.S. utilities and major investment firms) and the DOE. A significant portion of the DOE's cost share is being contributed through in-kind technical support from Sandia.

FY94 Accomplishments

Major accomplishments during 1994 included the following: (1) State-of-the-art maintenance evaluation and planning software was integrated into the maintenance activities at the KJC power park. Full implementation of this software is expected to result in an O&M efficiency improvement of 20%. (2) Research developed a new solar pump seal and recommended other modifications to the pump that reduced maintenance costs at KJC by $250,000/yr. (3) Thirty plant-years of power production data for SEGS III through VII were analyzed and documented. The major factors that influenced annual solar-to-electric conversion efficiencies were identified. (4) Advanced flow meters were tested. A Vortex shedding flowmeter was identified as the preferred flowmeter. (5) The effect of mirror cleanliness on plant performance was quantified with the help of a new reflectometer developed by this program in FY93. (6) KJC staff consulted with Solar Two Project personnel regarding design and O&M issues important to solar thermal plants.

FY95 Task Description

The largest effort during FY95 will be to install state-of-the-art software that can be used to optimize plant efficiency. A commercially available product will be integrated into the control of SEGS VI. In addition, a separate engineering analyses will be performed at Sandia to understand and optimize part-load behavior of a SEGS plant. This activity should lead to an increase in power production. Following installation of the optimization software, the startup and control of several subsystems at SEGS VI will be automated. Increased automation will lead to reductions in manpower, plant-startup time, and operator errors. Other activities include (1) an evaluation of the cyclic duty experienced by valves and recommendation for changes in operating strategy and design to reduce failure rates caused by cyclic stresses; (2) estimating maintenance-efficiency improvements resulting from

installation of maintenance planning software in FY94; (3) optimization of mirror wash techniques; (4) development of in-situ repair techniques for broken heat-collection elements; and (5) continued consultation on the Solar Two Project.

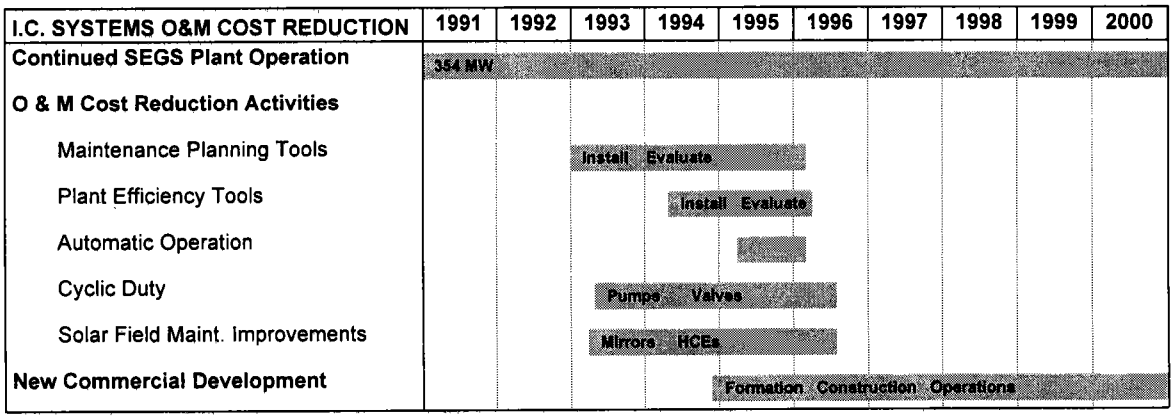
Major Milestones

Oct 94	Document advances made in FY94.
Apr 95	Fully implement plant-efficiency-optimization software at SEGS VI.
Aug 95	Complete automation of key subsystems at SEGS VI.
Sep 95	Complete and document engineering analysis of optimized efficiency.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	90	30	0	120
Contracts	780	20	100	900
Total	870	50	100	1020

Time Table



D. DESIGN ASSISTANCE

Objective

To accelerate the use of solar thermal systems through the following technology transfer activities: (1) direct assistance to end users of solar thermal technology by providing information about the selection, characterization, and performance of solar thermal systems, (2) cooperative solar thermal technology test, evaluation, and development efforts with the solar thermal industry, and (3) educating potential users and regulators about the economic performance and potential of solar thermal technology.

Rationale

In order to be effective, the solar thermal program requires a continual flow of information to and from the industry and users. The program's dissemination of research and development (R&D) results to industry, and the reciprocal communication of industry's needs to the program, are necessary to keep the R&D relevant and to ensure developments are rapidly implemented by industry. This activity is organized through the Solar Thermal Design Assistance Center (STDAC) at Sandia. The design assistance task fosters this flow of information by providing direct technical assistance to users and industry as well as through conferences, workshops, and publications. This task also provides an interface between the solar thermal programs, the Committee on Renewable Energy Commerce and Trade (CORECT), and the Solar Energy Industries Association (SEIA) to foster near-term applications of solar thermal systems in the international marketplace.

FY94 Accomplishments

In FY94, the STDAC's technology transfer recipients included state and local governments, foreign governments, military installations, industrial users of solar thermal technology, and the solar thermal industry.

The program helped states such as New Mexico and California with system refurbishments, proposals for new process heat and air conditioning systems and demand side management. Federal installations, including five military bases, were helped with similar proposals. The U.S. Corps of Engineers was supported in developing new methodology for assessing applicability of proposed systems. We are also supporting American Society of Heating, Refrigeration, and Air-conditioning Engineers by increasing visibility of solar concepts to their members, and participating in development and testing of a variety of process heat systems, components, and advanced instrumentation,

The Solar Thermal Design Assistance Center (STDAC) is providing technical assistance to the solar industry, including support for California's Solar Electric Generating System (SEGS) operators—the Daggett Leasing Corporation (DLC), the Kramer Junction Company (KJC), and the UC Operations Services—regarding the operation and maintenance of their utility-scale SEGS plants. An aerial flyover of the Solar Energy Generating Systems (SEGS) fields, during operation, is a project being organized to assess the tracking quality of the parabolic collectors. By observing the illuminated receiver of the collector, from the appropriate flying altitude, a qualitative measure of collector alignment can be measured.

Sandia has been conducting environmental tests on a complete LS-2 replacement facet built by Industrial Solar Technology (IST). This facet is needed as a replacement for broken glass mirrors in the SEGS plants. Sandia also worked with IST to analyze the performance of the solar trough hot-water system that was damaged by high wind in Tehachapi, California, and has completed performance testing on IST's trough collectors.

Technical support for international solar energy projects continues. Sandia's Photovoltaic and Solar Thermal Design Assistance Centers are cooperating to help the Mexican government apply renewable technologies in Mexico—including the use of solar ovens, ice makers, and dish/Stirling systems. Also, the STDAC and the photovoltaic program are supporting the application of solar thermal technology within the multi-million dollar USAID/Mexico program.

The primary focus of the STDAC's education activity was organization of the solar thermal program's major annual conference, Soltech 94. Also in its education efforts, the STDAC responded to around 1000 requests for information about solar thermal technology.

FY95 Task Description

The STDAC at Sandia will receive requests for assistance and will coordinate efforts with NREL to provide information and to fulfill industry requests for technology evaluation and development; application screening; and data and design evaluation to assist industry and users in implementing solar thermal technology. A new focus of this activity will be the application of Sandia's manufacturing capability to help the industry solve problems that involve manufacturing processes such as welding, materials processing, adhesives applications, machining, and computer-aided design. In addition, we will implement specific activities in support of new power tower and dish/engine initiatives, industry CRADA support, and coordination of dish/engine siting for reimbursable activities.

One of the major focuses of these new activities will be in the international arena, primarily Mexico, where the STDAC will coordinate the introduction of trough and dish electric systems as appropriate. This activity will involve identifying appropriate Mexican agencies with which to partner, training these agencies about the application of solar electric technology, identifying appropriate sites for demonstration and/or production systems, technical assistance in the systems implementation, and assistance in monitoring performance.

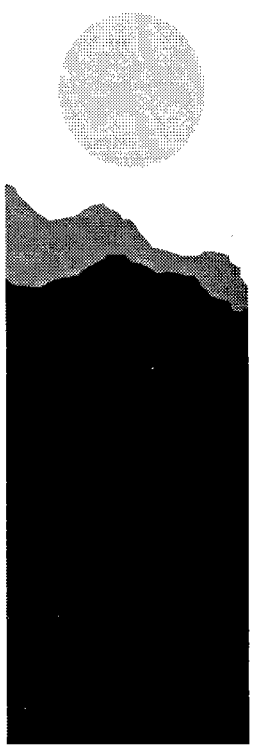
The primary focus of our educational activity is Soltech '95, where sessions will be conducted jointly with industry for specific federal, state, and local agencies, and international audiences that are interested in using solar thermal technology.

Major Milestones

Mar 95	Document FY94 STDAC activities.
Apr 95	Participate in Soltech '95.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	500	130	0	630
Contracts	270	0	350	620
Total	770	130	350	1250



E. SOLAR MANUFACTURING INITIATIVE

Objective

To develop manufacturing technology and processes that will permit cost-effective deployments of solar thermal systems in low-volume, early commercial applications; to reduce uncertainty in the cost and reliability of key solar components in order to improve financing of early commercial systems and reduce the risk of performance warranties; to promote the development of system-level business plans and industrial partnerships linking manufacturing scenarios to commercial sales prospects; and to establish the manufacturing basis for achieving the substantial cost reductions possible through higher volume production.

Rationale

Solar thermal technologies offer considerable promise as clean, inexpensive sources of electric power. Progress in the DOE program in collaboration with private industry has brought power tower and the dish/engine technology to the point where remaining technical issues that inhibit commercial sales are expected to be resolved over the next few years. The final hurdle for these technologies is not a technical barrier but a business barrier: how to develop system designs and manufacturing processes that will allow the early sales necessary for commercial demonstration of the technology and the creation of a viable U.S. solar thermal electric industry.

The solar thermal industry today faces a market environment with opportunities, but also challenges. At least two new technologies, the power tower and dish/engine systems, will be technically ready for commercial deployment within the next few years. Utilities and PUCs express growing interest in these technologies, and there also appear to be international opportunities for sales. The market environment will, however, be difficult to penetrate quickly given fairly stable fossil fuel prices and attractive competing technologies. The Solar Thermal Manufacturing Technology (SolMat) Initiative is aimed at reducing the cost of solar thermal technologies in an environment of uncertain future sales and modest initial production volumes. In this way, SolMat will fill a critical need for allowing solar thermal manufacturers to produce cost-effective products even before market demand will support high volume production.

FY94 Accomplishments

Three significant accomplishments occurred during FY94 under the SolMat initiative. First, a Request for Proposals entitled *Heliostat Manufacturing for Near-Term Markets* was issued, proposals were received, and reviews of the proposals were completed. The main objectives of this procurement are developing heliostat manufacturing technologies and production scenarios, determining heliostat costs, and developing market strategies, all consistent with near-term markets. Multiple contract awards are expected in early FY95.

Second, an announcement of a general SolMat procurement was made. In this announcement, industry interest in a wide range of manufacturing-related activities was sought. Suggested activities could range from manufacturing improvement studies for existing solar hardware up to large manufacturing validation efforts. These projects are intended to develop improved methods of manufacturing and product deployment that will make the industry more competitive in early markets.

Third, under the SolMat initiative, solar manufacturers are being offered an opportunity to learn a manufacturing technology called Design for Manufacturing Assembly (DFMA). This manufacturing technology is used by industry to effect significant cost reductions in large-scale manufacture. The technology, which was developed by Hughes Aircraft Co., typically results in 30% to 40% reductions in manufacturing costs and has been used successfully by a number of U.S. firms. The course will be offered first to Science Applications International Corp. and Cummins Power Generation, Inc., the two partners in the Utility-Scale Joint-Venture Program.

FY95 Task Description

During FY95 at least two requests for proposals (RFPs) will be issued under the general SolMat procurement. These requests will be in response to industry feedback on the announcement made in late FY94 and on feedback from the SolMat advisory group. Awards for this procurement will be made in FY95. The specific topics for funding will fall into two general categories. First are manufacturing

improvements that are targeted toward companies with near-term commercially viable products. However, these companies require improved methods of manufacturing and product deployment that will make the industry more competitive in early markets. Second are validation and implementation projects that are intended to demonstrate improvements in manufacturing and deployment and to provide confidence in the cost and reliability of the components.

Cost sharing will be a requirement for both of these types of projects with the degree of cost share dependent on the total funding requirement and the risks involved in the project.

Also in FY95, DFMA courses will be offered to new industry partners. The most likely candidates, after the USJVP partners described previously, are participants in the SolMat heliostat manufacturing contract.

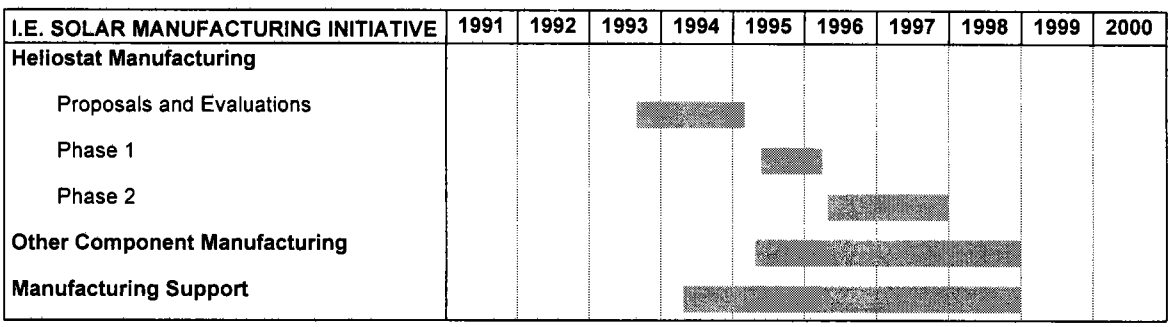
Major Milestones

Jan 95	Complete first DFMA class and evaluate effectiveness.
Apr 95	Release first RFP for manufacturing improvement projects.
Jun 95	Initiate Phase 1 heliostat contract.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	150	200	0	350
Contracts	0	1512	165	1677
Total	150	1712	0	2027

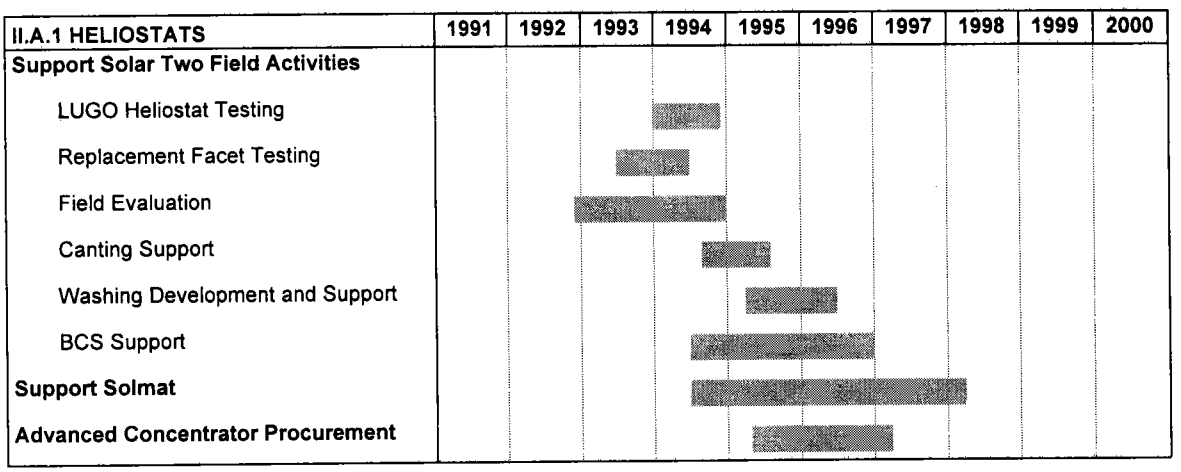
Time Table



Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	400	0	0	400
Contracts	400	0	0	400
Total	800	0	0	800

Time Table



2. PARABOLIC DISHES

Objective

To develop parabolic dish concentrator technology for use in dish/engine electric and other solar thermal systems.

Rationale

The parabolic dish is the largest cost element in a dish/Stirling system. It is also the first of the system components (i.e., the dish, receiver, and engine) whose performance determines the overall efficiency of the system. Therefore, it is essential that parabolic dishes have a high level of optical performance at low cost if these systems are to achieve commercial market penetration.

Current development activities in the Parabolic Dish task include the following: providing design and testing support for the Dish/Stirling and Utility-Scale Joint-Venture programs; developing advanced and field-test capabilities for evaluation of dish concentrators; and continuing to develop the single-element, stretched-membrane dish.

FY94 Accomplishments

In FY94, we completed testing and evaluation of the faceted, stretched-membrane dish with elastically-formed facets aligned at the longer focal length that is being used on Science Applications International Corporation's USJVP dish. Also, the dish's plastically-formed facets, made by Solar Kinetics, were installed. While researchers were preparing to test the dish, high winds destroyed the facets and seriously damaged the dish structure. Testing of the faceted, stretched-membrane dish was terminated.

A request for proposal was sent to Solar Kinetics asking company personnel to define a commercialization partner and a product that would incorporate the single-element, stretched-membrane dish. The proposal was received and is currently being evaluated. Any possible award would be made during FY95.

Two other FY94 activities were development of a 2-*f* method for characterizing facets and dishes, and merging the advanced heliostat and advanced dish concentrator activities. With the concurrence of the DOE, we merged the two advanced concentrator development activities into a single procurement that will emphasize the application to dishes and heliostats of new and/or unique concepts and proven manufacturing techniques that may currently be used in other industries.

FY95 Task Description

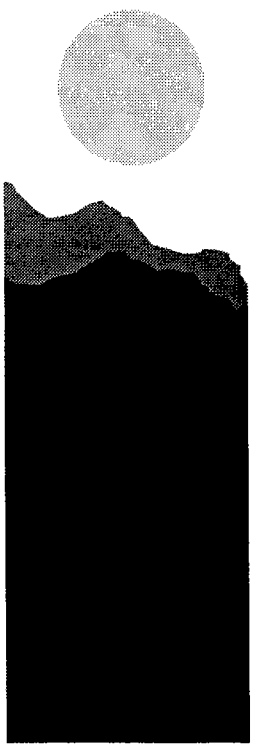
During FY95, we will continue to support the Dish/Stirling and Utility-Scale Joint-Venture projects with issues related to the design, testing, and evaluation of solar concentrators. We will continue to develop, evaluate, and apply testing techniques for dish concentrators. Lastly, we will release a request for quotation (RFQ) and place contracts for the development of advanced concentrator concepts (including heliostats).

Major Milestones

Mar 95	Complete initial testing of the SAIC dish.
May 95	Release the advanced concentrator RFQ.
Jun 95	Complete development of color 2-*f* system.
Sep 95	Place several small contracts to evaluate advanced concentrator concepts.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	370	0	0	370
Contracts	280	0	0	280
Total	650	0	0	650



Time Table

II.A.2 PARABOLIC DISHES	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
JVP Support										
2-F Development										
Site Support										
Advance Contractor Development										
Single Element Dish Development										

3. OPTICAL MATERIALS

Objective

To perform appropriate research and development (R&D) to obtain concentrator reflector materials that have improved durability and performance, increased service lifetimes, and decreased cost.

Rationale

Lightweight, durable, and efficient optical reflector materials are necessary to achieve cost and performance goals needed for commercialization of various solar thermal concentrator technologies. The reflector material is a common element in all solar concentrators. High specular reflectance with long service life, low cost, and ease of replacement in the field are key requirements.

FY94 Accomplishments

Task activities during FY94 emphasized improving the durability of advanced optical materials, reducing their cost, and increasing the confidence in the materials' lifetime in commercial applications.

During the past year, significant progress has been made in the development of advanced reflector materials for solar concentrator applications. Collaborative cost-shared R&D with industrial partners resulted in several advances. A commercial silvered-polymer solar reflector (designated ECP-305+ by 3M Company) that offers increased durability in terms of corrosion degradation and delamination resistance, was developed. Samples of an all-polymeric reflector material were prepared by the Dow Chemical Company of Midland, Michigan. The increased potential of silvered Teflon™ as a candidate mirror material was demonstrated.

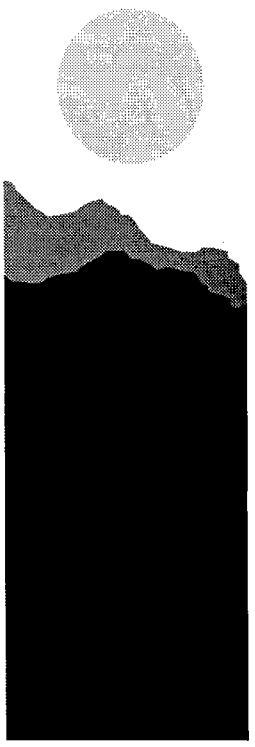
Significant progress has also been made in NREL's outdoor exposure test program. Five outdoor test sites are presently in operation where reflector material performance data and meteorological data are collected in a routine manner. At least one additional site, a coastal/marine environment to emulate a remote island location for remote power markets is being considered. The International Energy Agency's (IEA's) SolarPACES group has expressed an interest in becoming involved with NREL's outdoor test program and this opportunity is being pursued. A performance database has been developed to facilitate analysis of optical measurements that are made to track optical durability of mirror samples. A database program is being developed under a subcontract to organize, analyze, archive, and perform quality control tests on the meteorological data.

In addition to continuing traditional support activities of testing materials for industry and technical outreach activities, NREL has broadened industry support activities. Prospective solar manufacturers have expressed keen interest in test deployments of ECP-305+. NREL has provided significant qualities of ECP-305+ to interested solar manufacturers for field-deployment/demonstration purposes. Industrial Solar Technology has begun a commercial solar heat project using ECP-305+ as the reflective surface for a parabolic trough. The project will deploy approximately 630 m^2 of troughs to provide hot water for a Colorado prison. NREL has also provided roughly 720 m^2 of ECP-305+ to Cummins Power Generation for field-deployment/demonstration purposes associated with their Dish/Stirling Joint-Venture Project. These cooperative efforts dramatically demonstrate an effective interaction (aimed at commercialization of solar thermal electric systems) between NREL, the solar manufacturing community, and the polymer-film/metallization industry (e.g., 3M).

FY95 Task Description

During FY95 the optical materials program will be organized around the following tasks:

As a continuation of the initial FY92 program, the advanced reflector development program aims at expanding the number of candidates for low-cost, high-performance reflector materials. The majority of this work will be carried out in collaboration with industry. In FY95, one or two promising new candidates will be investigated. A systems analysis study will help evaluate advanced materials and determine which R&D directions are most likely to produce more effective materials than those used in current glass reflectors.



The FY95 outdoor optical testing program will press forward from successful FY94 activity. One additional outdoor exposure test site representative of a coastal environment will be activated. Collaboration with the international community through the IEA will be pursued. Additional candidate materials will be tested as appropriate.

Our industry support program will aim to provide industry with testing capabilities,

respond to critical industry needs in optical materials testing and/or development, and facilitate technology transfer to the industry.

Our materials testing program includes ongoing laboratory testing of materials durability and failure mechanisms.

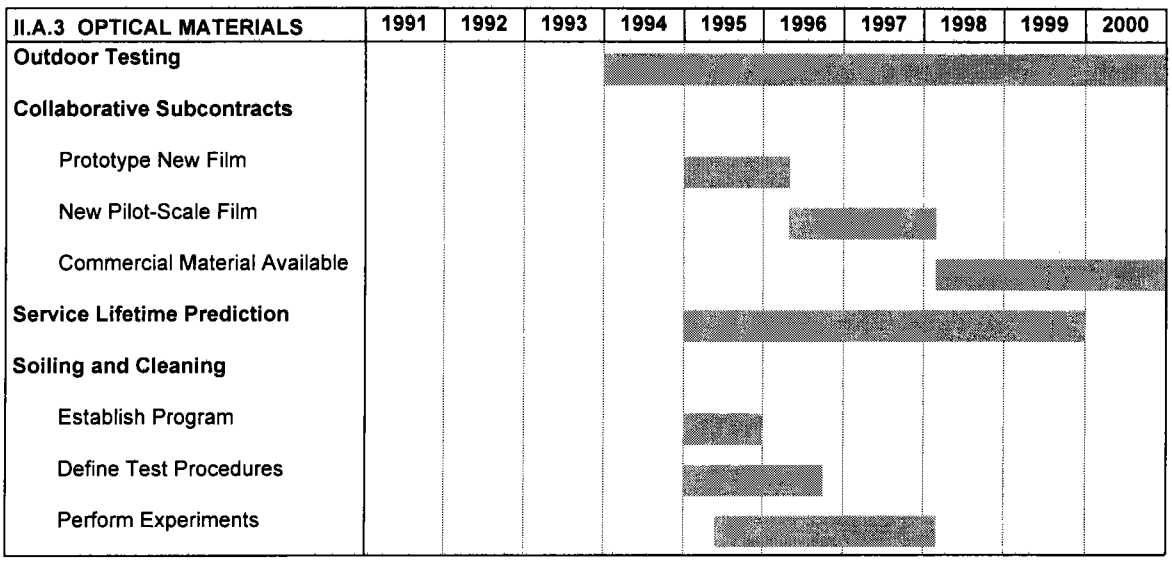
Major Milestones

Dec 94	Establish industry research collaborative.
Apr 95	Activate sixth outdoor test site.
Aug 95	Document status of outdoor testing activities.
Sep 95	Document alternative reflector materials R&D progress.
Sep 95	Document advanced reflector materials system study.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	0	654	0	654
Contracts	0	299	0	299
Total	0	953	0	953

Time Table



B. POWER CONVERSION

1. POWER TOWER TECHNOLOGY

Objective

To design, develop, and evaluate power tower technologies in direct support of the commercial applications programs and investigate advanced systems for future applications.

Rationale

The power tower cooperative projects are supporting the development of the Solar Two Project, a 10-MW_e project to validate the molten-salt power tower technology as the final step toward commercialization. Even though the molten-salt power tower technology is nearing commercialization, there are numerous areas where experimental and analytical work are necessary to demonstrate, optimize, and refine system designs and operating procedures. Our expertise in analytical and experimental work will be utilized to optimize and refine system designs, components, and procedures, and to ensure the technical success of the Solar Two Project and the commercialization of this technology. The work performed will be at the request of the Solar Two Project team, steering committee, and the power tower industry. In order to support future commercialization efforts, advanced power tower systems with potential performance and economic advantages are also being studied and tested.

FY94 Accomplishments

The emphasis of the power tower technology program in FY94 was to support commercialization efforts, specifically Solar Two. In addition, work to investigate advanced systems, both the Internal Film Receiver System and Air Receiver System, was also conducted. During the past year the following was achieved:

Sandia provided technical support to the Solar Two Project by chairing and participating in the Technical Advisory Committee and providing input to and review of system specifications and proposals, design requirements, and assessments of existing facilities at Solar One. A number of test programs were started and completed this past year in support of the molten-salt power tower development.

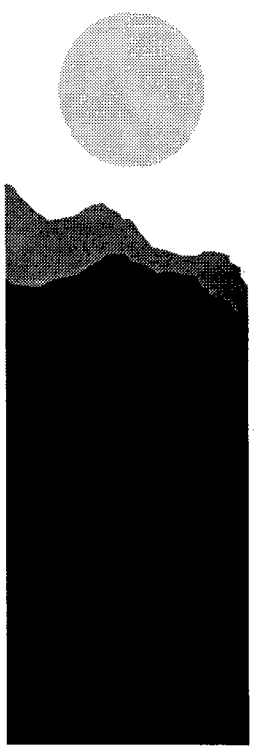
We completed a 4000-hour thermal cycling test program to assess the corrosion effects of alternative nitrate molten salts in a thermal cycling environment. The conclusions of these tests were that thermal cycling does not significantly increase corrosion rates 304 stainless steel and 316 stainless steel compared to previous static corrosion tests. We also completed a number of nitrate-salt component tests on the molten-salt loop. Testing and analysis of the nitrate salt freeze/thaw phenomenon continued with the interest of "cold starting" the receiver and salt piping. A number of valves and flanges were tested this year at the request of industry. The test results will impact the specifications and procedures for Solar Two and commercial receivers.

We continued testing to evaluate photometers that measure flux on the receiver. Both Bechtel and Rockwell were interested in replacing the flux gages in the receiver with photometers to provide input to the control algorithm. Sandias tests demonstrated that the photometers were accurate and more reliable.

We also initiated a cooperative effort among scientists in Spain, Germany and the United States to test the Receptor Avanzado de Sales (RAS) internal molten-salt film receiver. Sandia has continued to support the design and fabrication of the test, and we will participate in the testing of this receiver concept. The RAS, located at the Plataforma Solar de Almeria, has been fabricated and water tested. Salt flow in the loop has been delayed because of heat trace and control problems.

We are completing the study with the California Energy Commission to compare solar and fossil fuel power plants. The study compared the taxes paid by each plant under a various taxation scenarios and showed that the tax burden on a solar plant is much higher than an equivalent fossil fuel plant. Tax equalization strategies were recommended in a draft report.

The first-order analysis of a hybrid Combined Cycle Power Tower (CC/PT) concept was completed to allow a comparison with solar-only plants and gas-only combined cycle plants. The results show that the CC/PT has several important benefits and should be considered further as an alternate commercialization path for power tower technology.



FY95 Task Description

A significant amount of the work in Power Tower Technology will focus on supporting Solar Two Project. In addition, the study and testing of advanced power tower systems will continue in FY95. Specifically, we will continue to support the Solar Two Project team and the Solar Two Participants in the specification, design, and fabrication of Solar Two. This support will be in the form of programmic support, design reviews, systems analysis, technical consulting, and testing for all aspects of the project. We will continue the molten-salt flow loop testing program to evaluate heat trace, instrumentation, components, and panel startup and operation issues.

We will complete salt freeze/thaw experiments that quantify the effects of thawing salt in frozen pipes. We will also study and conduct experiments to examine cold filling of salt lines in the receiver, riser, and downcomer. Cold filling of salt lines can reduce the parasitics in a commercial plant by minimizing the heat trace requirements. We will implement thermal cycling corrosion testing of advanced receiver materials in cooperation with Rockwell. The thermal cycling corrosion tests will provide data (for 2400 hours and 300 cycles) on advanced inconel materials that may be used in a future advanced receiver.

An analysis of the taxation of solar thermal plants in the state of Nevada will be performed. The study will employ the methodology developed in cooperation with the California Energy Commission during FY94. The results will be presented to the Solar Enterprise Zone project developers to aid them with their efforts in the state of Nevada.

We will initiate and complete planned testing of the RAS. Fabrication of the 500-kW_t RAS will be completed and the concept validation tests completed. If the validation testing is successful, we will initiate a system evaluation to study the benefits and prepare a development plan.

In FY95, more detailed analyses will be performed on the CC/PT concept, specifically incorporating DELSOL/SOLERGY runs to better quantify the annual thermal energy delivered by the solar plant. In addition, we will continue to work with utilities and industry on further hybrid concept development.

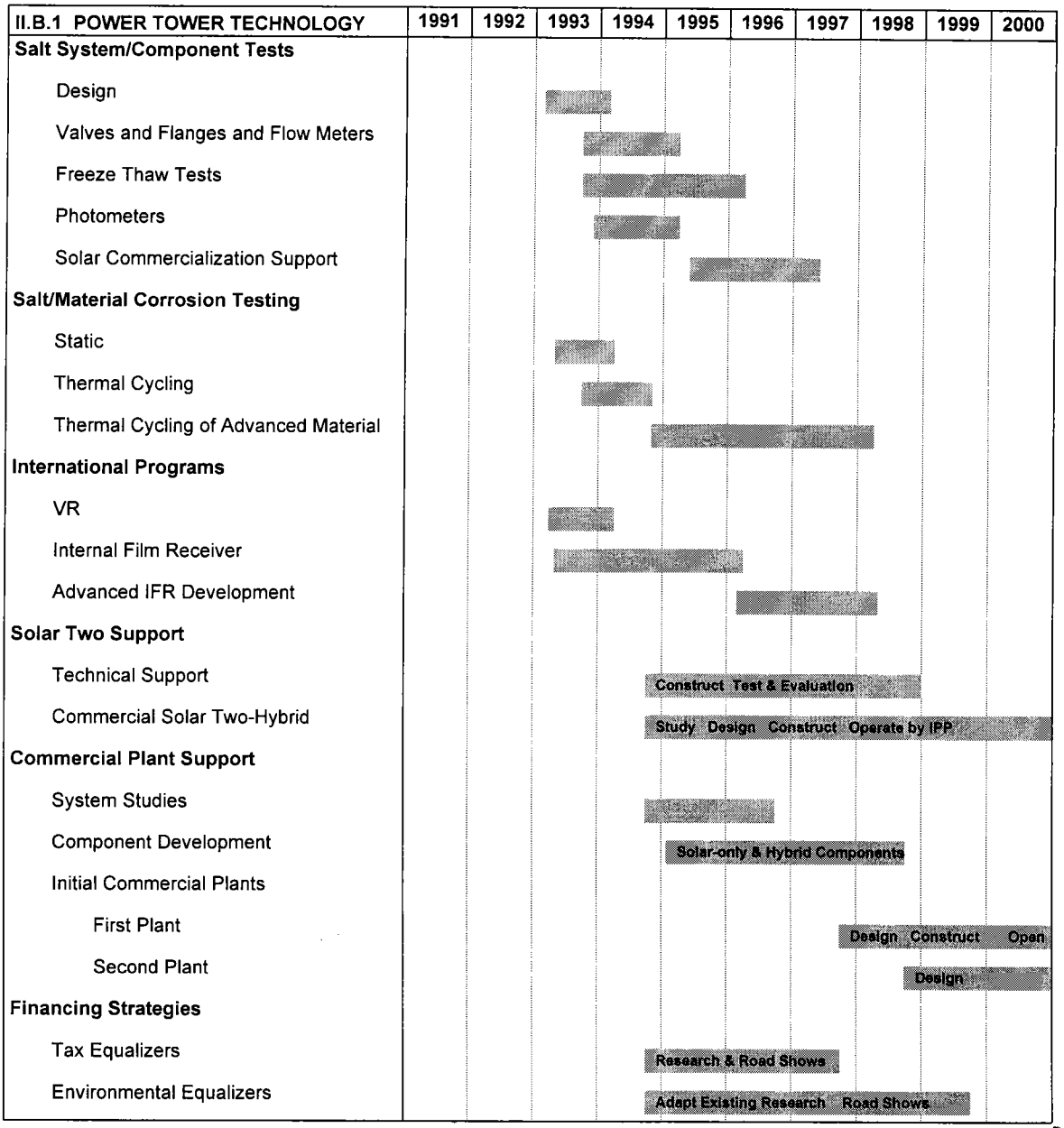
Major Milestones

Nov 94	Hold hybrid workshop at NREL.
Jan 95	Report on salt component and panel tests.
Mar 95	Complete the freeze/thaw tests on receiver tubes.
Jun 95	Complete initial evaluation of CC/PT project for Sacramento Municipal Utilities District service territory.
Jul 95	Complete study of tax equity for state of Nevada.
Aug 95	Complete testing of Solar Two heat trace.
Sep 95	Complete testing of the 500-kW_t RAS internal molten-salt film receiver at the Plataforma Solar de Almeria.
Sep 95	Complete the Transient Salt freezing in pipes and planned thermal cycling corrosion testing of stainless steels.

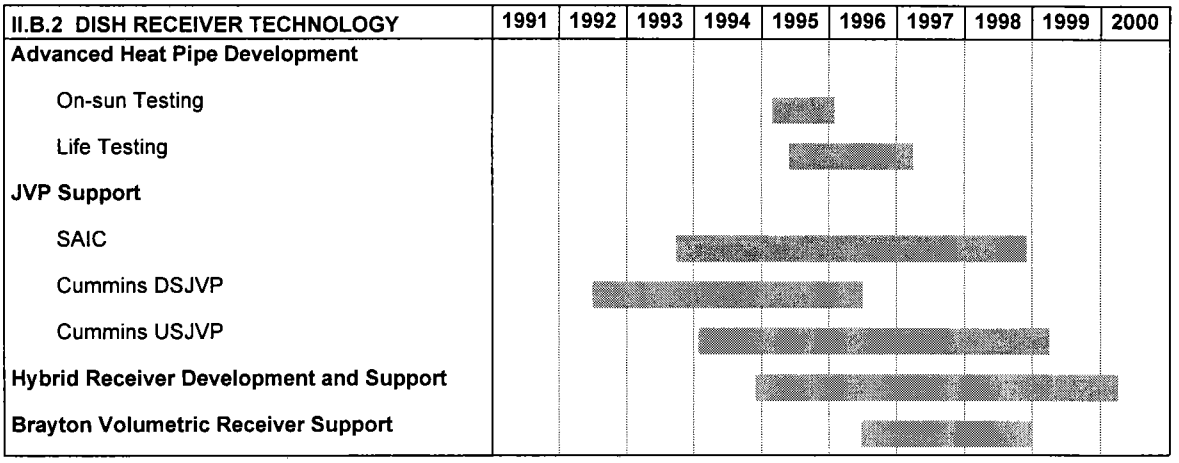
Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	460	263	0	723
Contracts	390	81	0	471
Total	850	344	0	1194

Time Table


II.B.1 POWER TOWER TECHNOLOGY
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Salt System/Component Tests
Design
Valves and Flanges and Flow Meters
Freeze Thaw Tests
Photometers
Solar Commercialization Support
Salt/Material Corrosion Testing
Static
Thermal Cycling
Thermal Cycling of Advanced Material
International Programs
VR
Internal Film Receiver
Advanced IFR Development
Solar Two Support
Technical Support
Construct Test & Evaluation
Commercial Solar Two-Hybrid
Study Design Construct Operate by IPP
Commercial Plant Support
System Studies
Component Development
Solar-only & Hybrid Components
Initial Commercial Plants
First Plant
Design Construct Open
Second Plant
Design
Financing Strategies
Tax Equalizers
Research & Road Shows
Environmental Equalizers
Adapt Existing Research Road Shows

Time Table


II.B.2 DISH RECEIVER TECHNOLOGY
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Advanced Heat Pipe Development
On-sun Testing
Life Testing
JVP Support
SAIC
Cummins DSJVP
Cummins USJVP
Hybrid Receiver Development and Support
Brayton Volumetric Receiver Support

3. DISH CONVERTER SOLARIZATION–

Objective

In cooperation with industry, to test and evaluate conversion devices to solve integration issues that are inherent to dish/engine conversion systems.

Rationale

Stirling engine-based systems have been identified as the most efficient solar-to-electric power conversion systems (PCSs) available. With a demonstrated net efficiency of 29.4%, a dish/Stirling system holds the record for solar-to-electric power conversion. The individual components required for a dish/Stirling system and its prototype, non-optimized systems, have been demonstrated. As the systems progress from demonstration phases towards commercialization, integration of the components and system optimization have become increasingly important. Brayton engine-based systems, on the other hand, have a substantially larger technology base as well as a demonstrated reliability base, but they have not demonstrated efficiencies as high as those of the Stirling system. This makes Brayton engine-based systems a logical back-up technology to Stirling systems.

Component integration issues involve thermal and mechanical matching of the components, startup and transient control issues, sensor location, and design of auxiliaries. The optimization process involves trading off system parameters such as capital cost, operation and maintenance cost, system availability, performance, and system life to develop the most economically feasible system. Testing at Sandia will focus on performance characterization, system availability, and identification of system integration issues. The results and conclusions will be made available to the industrial community for use in optimization models and system design. These efforts will support both existing and new dish/engine joint-venture programs.

FY94 Accomplishments

The power conversion system based on the STM 4-120 Stirling engine was tested on-sun. A number of technical problems that occurred during testing were successfully addressed. The engine's on-sun operational characteristics were mapped.

Phase 1 of the contract with Northern Research and Engineering Corporation for the solarization of a 30-kWe Brayton engine was completed. The result was a report on the economic competitiveness of dish/Brayton power systems. Phase 2 of the project, which involves building and testing a solarized Brayton engine, was initiated. The solarized system will include a volumetric receiver being developed by the DLR (the German Aerospace Research Establishment), which is being funded by the German government.

FY95 Task Description

Operation and performance of a Stirling PCS, based on the Stirling Thermal Motors STM 4-120 engine and employing a heat-pipe receiver, will be characterized by a series of tests on a TBC. This reconfigured PCS will be characterized, and the results obtained will be compared to those obtained with the direct insolation receiver.

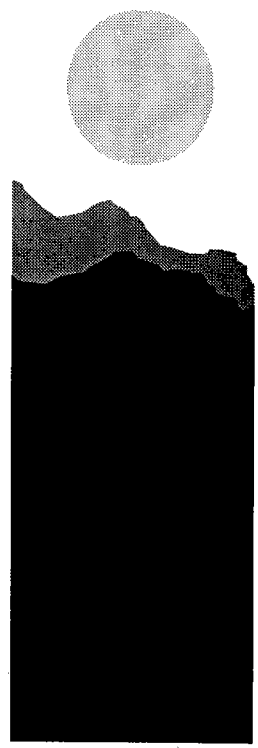
NREC will design and build a 30-kWe solarized Brayton engine. This engine will employ a DLR volumetric receiver. This engine will then be characterized by on-sun testing on a TBC.

Major Milestones

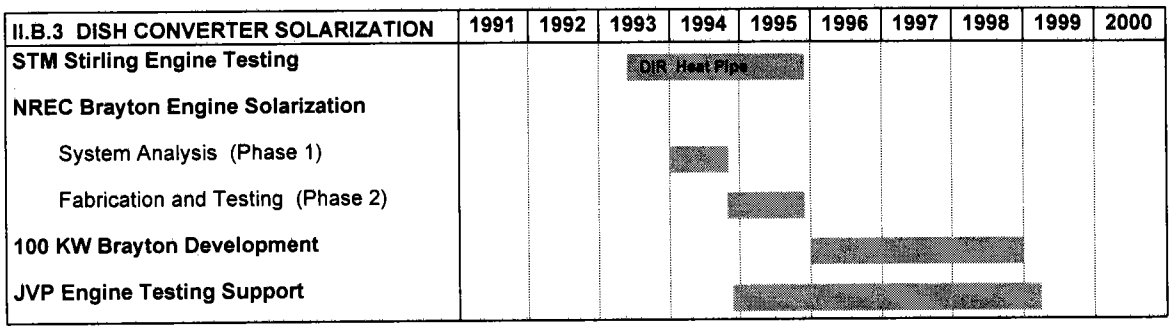
May 95	Complete on-sun testing of the Stirling PCS based on the STM 4-120 with a heat-pipe receiver.
May 95	Complete construction of the NREC solarized Brayton engine.
Aug 95	Complete on-sun testing of the NREC Brayton PCS.

Resources

($k)	Sandia	NREL	DOE	Total
FTE Costs	350	0	0	350
Contracts	500	0	0	500
Total	850	0	0	850



Time Table


II.B.3 DISH CONVERTER SOLARIZATION
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
STM Stirling Engine Testing
DIR Heat Pipe
NREC Brayton Engine Solarization
System Analysis (Phase 1)
Fabrication and Testing (Phase 2)
100 KW Brayton Development
JVP Engine Testing Support

C. TESTING TECHNOLOGY

Objective

To maintain and operate the National Solar Thermal Test Facility (NSTTF) in support of Solar Thermal Electric Program objectives.

Rationale

The United States Department of Energy's NSTTF, located at Sandia National Laboratories in Albuquerque, New Mexico, is the major facility for testing of solar thermal components and systems in the United States. The facility is also a DOE Designated User Facility. Originally constructed as the Central Receiver Test Facility in the late 1970's, its mission has been expanded to include distributed receiver technologies, and it now includes line-focus and point-focus collectors, two solar furnaces, and an engine test facility. In addition, the unique capabilities of the facility have been applied to a wide variety of tests unrelated to solar energy, but using the intense heat from concentrated solar radiation or using the large-scale optical systems at the site.

The facility incorporates both permanent test capabilities, such as the heliostat field and test bed concentrators, and experiments installed for one-time evaluation, such as the LaJet Innovative Concentrator and the large-scale water flow test. Some of these latter type of experiments become useful for application to later programs, such as the parabolic troughs from the Modular Solar Industrial Retrofit program that were modified and used in support of the Solar Detoxification of Water experiments conducted by the Solar Industrial Program. Test apparatus installed under Work for Others programs have also become permanent facility assets, such as the NASA-funded tracking truss used for dish-facet evaluation.

Over time, permanent test capabilities require upgrade to maintain their capability. In addition, equipment installed for one-time tests needs to be removed when the probability of future use is outweighed by the cost of maintaining the equipment in safe condition. Ever changing and increasingly stringent ES&H requirements also must be implemented. Among these that will go into effect at Sandia in the near term is increased formality in maintenance of equipment.

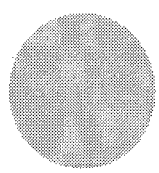
FY94 Accomplishments

In recent years, a major focus of NSTTF maintenance and upgrade has been in bringing the facility into formal compliance with ES&H requirements. Through various inspections and audits, including a DOE Tiger Team, the facility has established a reputation for excellence in Environment, Safety, and Health.

More recently, various facility capabilities have been upgraded. Among these are the refurbishment of the mirror facets on TBC #1. In addition, five major receiver tests were completed on the TBC in FY94 and on-sun testing of the Stirling Thermal Motors engine package was continued.

Other accomplishments include: shakedown testing of the STM 4-120 engine; long-term, bench-scale receiver durability testing; bench-scale, metal/felt receiver testing; completion of testing of the faceted membrane dish; and completion of testing of the Industrial Solar Technology trough. A number of tests were completed in support of the Solar Two program, including testing of salt-panel fill and freeze/thaw procedures, testing of in-salt instrumentation and valves, and assessment of alternate temperature and flux characterization methods that are possible during normal operations.

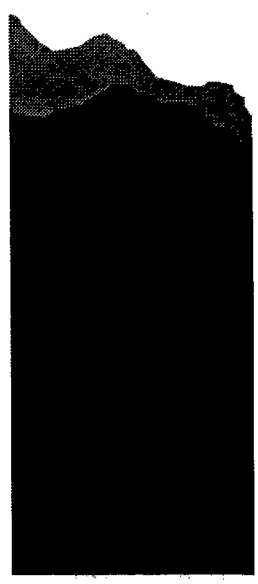
A severe wind storm damaged three prototype heliostats, the faceted dish, some of the existing Modular Industrial Solar Retrofit systems, and the Power Kinetics Small Community Solar Experiment #2. The safety hazards associated with the damaged equipment has been mitigated and the clean up work has been started.



FY95 Task Description

Major activities planned for FY95, as detailed in other tasks, include testing of the STM engine with the heat-pipe receiver, integrating the Thermacore receiver with new heater-heads, testing of the NREC Brayton cycle engine, and performing molten-salt corrosion tests.

Among upgrades planned in FY95, the control system for the Test Bed Concentrators will be replaced. The current control system



is 15 years old, and failures of this system have interfered with productivity. Often, only one of the two control systems has been available, allowing operation of only a single TBC.

The NSTTF's heliostat field remains operational, in part because of reimbursable programs that have supported continued maintenance and use. No upgrading of the field controls are necessary to support current tests, but the availability of spare parts is declining and may soon be a problem. A plan to maintain and upgrade the field controls will be prepared so that upgrading could be initiated whenever future tests would require it.

Removal of a number of older, unneeded systems will be initiated as time permits:

- The Category B molten-salt receiver has been partially dismantled to provide components associated with tests supporting the Solar Two program. In addition, a number of engineers associated with the Solar One Project have been given detailed tours of the receiver to pass on Sandia molten-salt expertise. As the Solar Two program moves forward, the need for this receiver will decline and dismantlement can be completed.

- Some of the existing Modular Industrial Solar Retrofit systems will be removed. One of these systems was converted earlier to serve the solar-detoxification-of-groundwater program. However, all of the systems were damaged by very high winds and some of the systems are no longer suited for future use; portions of all of the systems, such as the steam skids, are unlikely to be needed again. Sufficient capability to support as-yet-undefined future needs will be maintained.

- The LaJet Innovative Concentrator has already been stripped of all of its facets in support of the Cummins Dish/Stirling Joint Venture Program project. This dish is larger than needed for 25-kWe applications. Furthermore, it is not expected that a 25-kWe system would use a polar mount. Dismantlement of this system will be completed as resources allow.

- The condition of the Power Kinetics Small Community Solar Experiment #2 Verification Module has deteriorated because of high winds. The system has to be removed because it now poses a safety risk. This system is still owned by Power Kinetics. Negotiations will be completed and the system removed.

Milestones

Programmatic milestones for testing technology are addressed in each of the technology sections.

Resources

The National Solar Thermal Test Facility activities, including maintenance and upgrade, are funded proportionately by all users, the majority of which are associated with the solar thermal electric program. No special category of funds for upgrade is established. Funding is a part of all users' programs. A special fund may be established to defray the cost of the high wind damage cleanup.

III. REIMBURSABLES

Objective

To apply the National Solar Thermal Test Facility and other laboratory capabilities to work performed for non-DOE customers on a reimbursable basis.

Rationale

The laboratories will continue to perform work for others because (1) unique capabilities are made available to other government agencies and industry; (2) a number of synergies improve cost effectiveness and extend impact of program activities because complementary activities are performed and a larger and more flexible work force is maintained within the program; (3) forced shutdown of portions of the NSTTF because of budget limitations, such as the heliostat field and solar tower in FY91-92, is avoided and future DOE solar programs avoid high restart costs; and (4) customers are charged user fees that partially offset the operating and maintenance costs of the NSTTF, including all operating and maintenance costs for the heliostat field and solar tower in FY91 and FY92.

FY94 Accomplishments

In FY94, no reimbursable tests were conducted at the NSTTF. However, the NSTTF continues to be a unique resource for the solar thermal community.

FY95 Task Description

Although the original test schedule has been delayed because of funding problems, Atlantis Energie, Ltd. of Bern, Switzerland, plans to install and test a larger volumetric central receiver.

The effort to increase accessibility to users as a Designated User Facility will continue. The User Facility designation significantly simplifies access to the test facility. However, the Sandia Work-For-Other's program no longer holds a $50,000 minimum and is also a useful tool for accomplishing reimbursable activities.

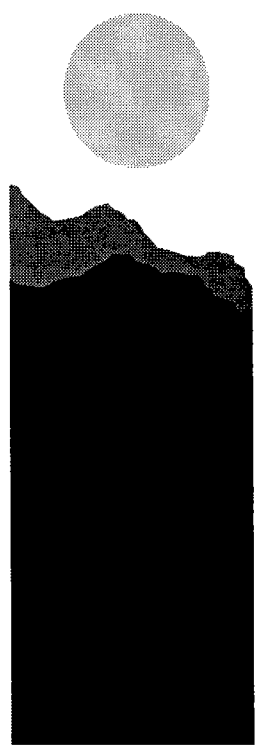
Other reimbursable projects include the Strategic Environmental Research and Development Program projects for the Cummins 7.5-kW_e dish/Stirling systems and an Army Corps of Engineers project to evaluate its computer modeling code.

Milestones

No program milestones. Individual reimbursable projects have milestones for their customers.

Resources

No Solar Thermal Electric Program resources are used to support reimbursable testing.



PROGRAM MANAGEMENT

The management and direction of the Solar Thermal Electric Program is structured to be responsive to national energy policy. That policy is provided by the Secretary of the Department of Energy and incorporates recommendations from the Executive Office, the Congress, national energy advisory boards, other government agencies, industry, universities and others. Sound management of the program is essential to ensure that the overall goals of the Solar Thermal Electric Program are appropriate and are met, and that the activities leading to those goals proceed in an orderly, cost-effective manner.

Implementation of the Solar Thermal Electric Program, as defined by the Multi-Year Program Plan, legislative requirements, resource availability, and the Annual Operating Plan requires careful tracking of research and development activities to assure satisfactory progress toward the overall programs goals. Milestones and decision points are established for each program task and are used to determine the necessity for redirecting activities in view of program priorities and available program resources.

Program Management and Organization

The DOE Solar Thermal and Biomass Power Division is one of two divisions reporting to the Office of Solar Energy Conversion under the Deputy Assistant Secretary for Utility Technologies. The Division is responsible for managing and reporting the status and progress of the Solar Thermal Electric Program. Policy formulation, planning, resource allocation, and evaluation activities are performed by the Solar Thermal and Biomass Power Division. DOE field offices and field laboratories have been assigned responsibility for implementing the program.

Field Laboratory Management and Organization

Specific implementation of the Solar Thermal Electric Program is assigned to two field laboratories, Sandia National Laboratories in Albuquerque, New Mexico, and the National Renewable Energy Laboratory (NREL) in Golden, Colorado. Together, these two field laboratories are responsible for implementation of the technology development activities and the specific commercial applications that have been formulated to meet the objectives of the program. Activities are conducted both in-house at the laboratories and through subcontracts (often cost-shared) placed with private industry, other research organizations, and universities.

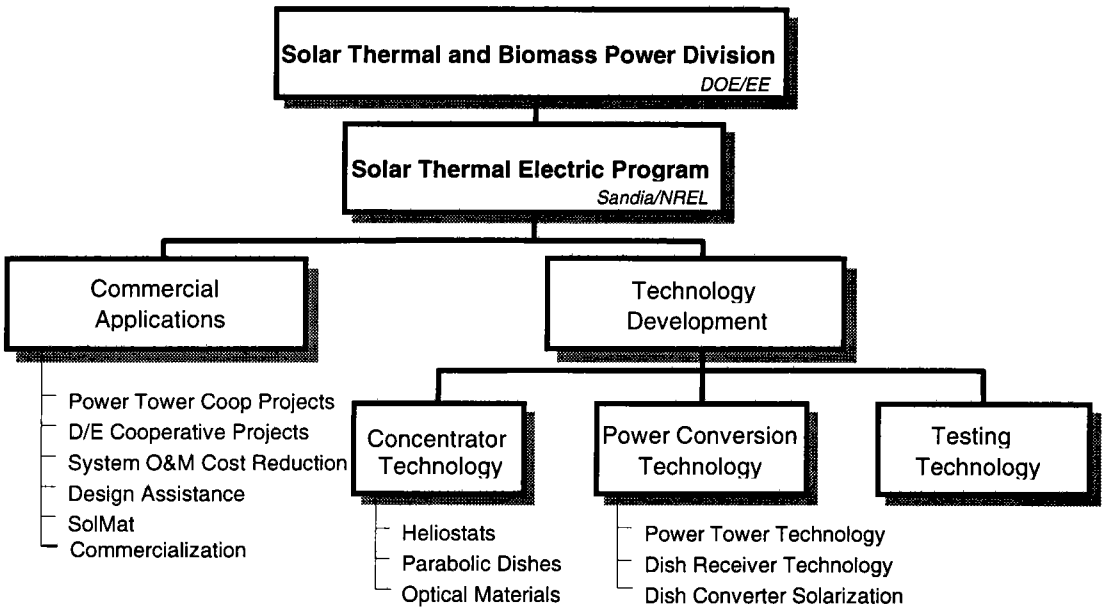
Sandia is the Solar Thermal Electric Program's lead laboratory. The program's management structure is shown below.

REPORTING

The DOE Solar Thermal Electric Program management is kept informed of program progress and management issues on a continuing basis through a variety of formal and informal means such as site visits, frequent telephone communication, weekly highlights, the annual Soltech conference, quarterly reports jointly issued by Sandia and NREL, semi-annual program reviews and other topical meetings, and a high-level annual summary. The Quarterly Report is the primary formal mechanism for documentation of program progress, current planning, budget status, and other relevant management information.

TECHNOLOGY TRANSFER

The Solar Thermal Electric Program supports a number of technology transfer-related activities to ensure the prompt, accurate, and continuous flow of significant research and technology development information to industry and other users. The primary technology transfer conduit is through Commercial Applications. The interactive nature of these joint industry/government activities makes frequent transfer of relevant technology an essential feature of these programs. Weekly newsnotes will provide first-level documentation of this technology transfer. The Solar Thermal Design Assistance activity is the program element that reaches the largest segment of current and potential users/suppliers of commercial solar thermal electric technology. More traditional means of technology transfer are also employed. Topical reports and publications are periodically prepared and distributed to document the status of the solar thermal electric technologies and projects. Technical reports and papers on all aspects of the program's research and development are published and widely distributed. Technical reports are submitted to the DOE Technical Information Center (TIC) at Oak Ridge, Tennessee, for entry into the national database on energy technology, and for sale



by the National Technical Information Service (NTIS). Sandia and NREL also make limited immediate distribution of technical reports to targeted industry, laboratory, and university representatives.

Each year, several meetings and workshops are conducted to bring interested organizations, as well as researchers, scientists, engineers, and users together in a technical forum to exchange technical and programmatic information. The DOE and the National Labs also participate in International Energy Agency (IEA) meetings and workshops. Industrial and end-user representatives and foreign and domestic researchers, scientists, and engineers are encouraged to visit the field laboratories, solar thermal project sites, and test facilities to exchange information and ideas. At a minimum, these meetings, workshops and visits will be documented by weekly newsnotes. Continuing academic and industry involvement through postdoctoral, sabbatical, visiting scientist, summer faculty, and student programs afford the opportunity for first-hand interactions with laboratory staff and facilities. Direct involvement in conducting significant portions of the R&D work through subcontracts to universities (including HBCUs) and industry offers a direct avenue for technology transfer and participation with the solar thermal community.

DOE/EE Solar Thermal Electric Program

FY95 AOP Budget (Per Burch 1/20/95 Budget)	Sandia			NREL			Other		Totals		
	FTE $	Contr	Total	FTE $	Contr	Total	Agency	Contr	FTE $	Contr	Total
Commercial Applications	**1890**	**8633**	**10523**	**390**	**1597**	**1987**	(1400/100)	**2483**	**2280**	**12713**	**14993**
CR Cooperative Programs	**600**	**0**	**600**	**0**	**0**	**0**	**GO/HQ**	**1500**	**600**	**1500**	**2100**
D/E Cooperative Programs	**550**	**7583**	**8133**	**30**	**65**	**95**	**HQ**	**368**	**580**	**8016**	**8596**
Cummins DSJVP	170	1100		30	65					1165	1165
Cummins USJVP	170	2600					HQ	368		2968	2968
SAIC USJVP	180	3500								3500	3500
New USJVP	30	383								383	383
O&M Cost Reduction	**90**	**780**	**870**	**30**	**20**	**50**	**HQ**	**100**	**120**	**900**	**1020**
SolarMAT	**150**	**0**	**150**	**200**	**1512**	**1712**	**HQ**	**165**	**350**	**1677**	**2027**
Design Assistance	**500**	**270**	**770**	**130**	**0**	**130**	**HQ**	**350**	**630**	**620**	**1250**
Technology Development	**2630**	**2020**	**4650**	**1125**	**555**	**1680**			**3755**	**2575**	**6330**
Concentrator Technology	**770**	**680**	**1450**	**654**	**299**	**953**			**1424**	**979**	**2403**
Heliostats	400	400	800		0	0			400	400	800
Parabolic Dishes	370	280	650		0	0			370	280	650
Optical Materials		0	0	654	299	953			654	299	953
Power Conversion Technology	**1860**	**1340**	**3200**	**471**	**256**	**727**			**2331**	**1596**	**3927**
Central Receivers	460	390	850	263	81	344			723	471	1194
Dish Receivers	1050	450	1500	208	175	383			1258	625	1883
Dish Converter Solarization	350	500	850		0	0			350	500	850
Total	**4520**	**10653**	**15173**	**1515**	**2152**	**3667**		**2483**	**6035**	**15288**	**21323**
Capital			**150**			**350**					**500**
Grand Total			**15323**			**4017**		**2483**			**21823**

DOE/EE:

R. Annan
G. Burch (3)
S. Gronich
T. Rueckert
R. Shivers
J. Kern
L. DiNunzio
M. Reed
F. Wilkins

DOE/AL:

D. Sanchez

DOE/GO:

F. Stewart
R. Martin

NREL:

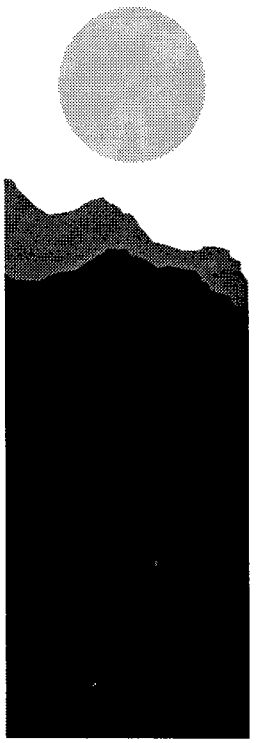
B. Marshall
R. Stokes
S. Hauser
J. Anderson
S. Rubin
T. Williams (15)

PERI:

D. Kumar

SANDIA:

D. Arvizu
P. Klimas
C. Cameron
J. Chavez (12)
C. Tyner (30)



SOLAR THERMAL ELECTRIC PROGRAM CONTACT LIST

DOE/EE

Gary Burch	202-586-0081
Sig Gronich	202-586-1684
Tom Rueckert	202-586-0942

Sandia Program Management

Craig Tyner, Technology Development	505-844-3340
Jim Chavez, Test Facility	505-844-4485
Paul Klimas, Renewable Programs	505-844-8159

Sandia Technology Development Staff

John Anderson	505-844-0800	Dave Menicucci	505-844-3077
Chuck Andraka	505-844-8573	Jim Moreno	505-844-4259
Rich Diver	505-844-0195	Tim Moss	505-844-7356
Lindsey Evans	505-844-2964	Jim Pacheco	505-844-9175
Don Gallup	505-845-8793	Mike Prairie	505-844-7823
Scott Jones	505-844-0238	Hugh Reilly	505-845-9811
Greg Kolb	505-844-1887	Bertha Stange	505-844-5330
Tom Mancini	505-844-8643		

Sandia National Solar Thermal Test Facility Staff

Phyllis Blair	505-845-3310	Jeannette Lloyd	505-845-7153
Patricia Cordeiro	505-845-3051	Rod Mahoney	505-845-3295
Bob Edgar	505-845-3450	Scott Rawlinson	505-845-3137
Jim Grossman	505-844-7457	Earl Rush	505-845-3331
Dick Houser	505-845-3448	John Strachan	505-845-3303
Bill Kolb	505-844-1935		

NREL Program Management

Tom Williams	303-384-7402
John Anderson	303-384-7422
Steve Hauser	303-384-7416

NREL Solar Thermal Staff

Mark Bohn	303-384-7405	Mark Mehos	303-384-7458
Rita Goggin	303-384-7449	Hank Price	303-384-7437
Mary Jane Hale	303-384-7453	Gena Ricciardi	303-384-7400
Gary Jorgensen	303-384-7473	Tim Wendelin	303-384-7475
Cheryl Kennedy	303-384-7408		

Industry

Cummins	Rocky Kobo	512-377-7171
SAIC	Kelly Beringa	303-279-5677
Bechtel	Pat DeLaquil	415-768-1947
SCE	Paul Sutherland	818-302-9724
KJC	Gilbert Cohen	619-762-5562